Flight Systems Research Quarterly

An informal newsletter by and for participants of the UCLA/NASA Flight Systems Research Center

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Dryden Becomes Newest NASA Center

NASA administrator Daniel S. Goldin announced on January 6 a number of management appointments and organization structural changes at NASA headquarters in Washington, DC and at various NASA field centers. Of particular interest to the UCLA/NASA-Dryden Flight Systems Research Center, effective March 1, 1994, the Dryden Flight Research Facility will be established as a separate entity, and will no longer be a part of the Ames Research Center at Moffett Field, CA. Kenneth J. Szalai, who currently heads Dryden as a deputy director of Ames, has been appointed as the new director of Dryden, reporting directly to Dr. Wesley Harris, Associate Administrator for Aeronautics.

"Operating as a separate facility, Dryden will be able to support the agency's aeronautics and space programs in a streamlined manner, by working directly to serve each of the research and flight centers," Goldin said. He said that Dryden will work with the centers and aerospace community customers to formulate and implement flight research and test programs and streamline program execution. "This change, reflects the commitment on the part of NASA to reduce layers of management and empower operating organizations to carry out their mission with maximum benefit to the country," the Administrator said.

The last operational F-104 at Dryden takes off for the last time for a final fly-over on February 4, ending a 30 year era of 104s at Dryden. Attached beneath the plane is the UCLA Transverse Jet Imaging Experiment (*see page 3*).

Aftershocks & Shock Waves

A sonic boom is the sound resembling thunder caused by an aircraft moving faster than the speed of sound. Though its affect on the general public is far less dramatic than an earthquake or aftershock, a sonic boom is sometimes mistaken as such.

The shock wave generated by a supersonic aircraft forms a cone of pressurized air molecules, on the order of a few pounds per square foot, which move outward and rearward in all directions and extend to the ground. As the cone spreads across the landscape along the flight path, they create a continuous sonic boom along the parabola of the cone's intersection with the ground. The resulting pressure pulse resembles an N-wave (*see figure below*). The sharp pressure drop, after the buildup by the incident shock wave, acts as a strong acoustic (pressure) wave, producing the audible sonic boom. For earthquakes, the geodetic pressure buildup and subsequent sharp release of energy result in seismic waves underground. Seismic instruments are so sensitive to disturbances that they can even detect shock waves aboveground. Last December, one of Dryden's SR-71s flew a supersonic flight to assist JPL in calibrating its seismic arrays over the Los Angeles area.

All aircraft generate two cones, one at the nose as well as at the tail. They are usually of similar magnitude and the time interval between the two as they reach the ground is dependent on the size of the aircraft and its altitude A small fighter type aircraft about 50 feet long produces shock waves less than 0.1 seconds apart, so that the human ear usually detects these as a single sonic boom. Longer aircraft, like the 122 feet long Space Shuttles, have shock intervals of about 0.5 seconds, making the double boom very distinguishable.

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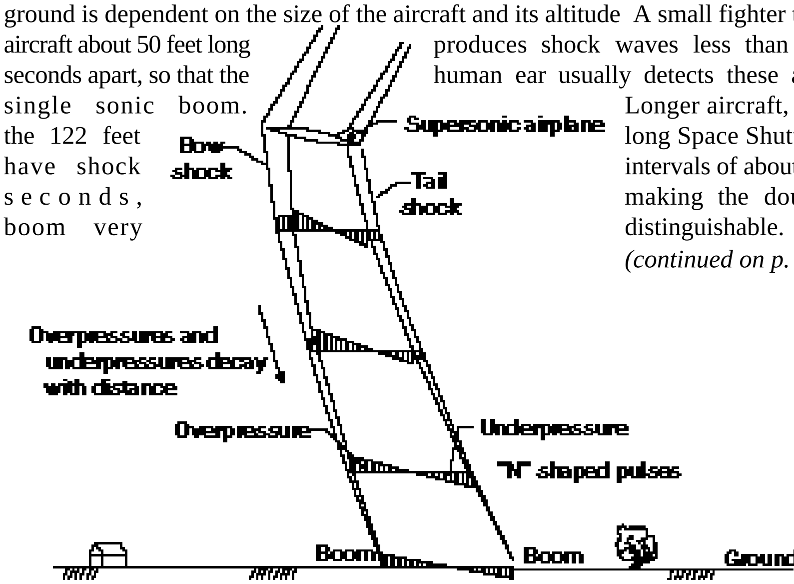

Sonic boom generation and pressure signature. (from NASA SP-367)

In this issue

Dryden Test Pilot Visits UCLA

NASA Ames-Dryden test pilot, Steve Ishmael, came to UCLA to give a talk to the student AIAA chapter on November 23 of last year. From an engineering point of view, Mr. Ishmael spoke about his experience flying the SR-71, explaining the many complex technical phenomena involved in flying a jet that cruises at Mach 3.2 at 85,000 feet. Mr. Ishmael also spoke about his key role in other flight projects such as the X-29 forward-swept wing demonstrator and the F-16XL supersonic laminar flow aircraft. He also lead a discussion about the High Speed Civil Transport and other things that were of interest to the students. The talk was especially meaningful to some of the senior aerospace engineering students, who were just finishing up classes in jet propulsion and aircraft stability and control. Mr. Ishmael had to leave soon after the meeting, saying, "I have to catch an early flight tomorrow morning." And we all knew what he meant.

(Thanks to John Griswold, UCLA AIAA President, for his assistance with the above article.)

Reminder:

The UCLA/NASA Colloquium '94 at Dryden is planned for sometime in May. Further details will be given in the near future. Despite the freeway problems around the Newhall Pass area due to the Northridge Quake, driving is only minorly affected for UCLA drivers since they are going against the flow of traffic. The I-5 to SR-14 interchange uses the previous truck route, and has an additional carpool (2+) lane both north and southbound.

NASA-UCLA Workshop on Laser Propagation in Atmospheric Turbulence

On February 1-3, the Flight Systems Research Center hosted a workshop at UCLA focusing on optical spectroscopy for atmospheric turbulence and environmental monitoring, featuring international and leading researchers in the field from industry, academia, and government. NASA Dryden participants included Rodney Bogue, L.Jack Ehernberger, and Dwain Deets.

An agenda and list of all the speakers' abstracts can be obtained from the editor of this newsletter. Topics included stochastic modeling of image propagation, aircraft and balloon measurements of temperature and refractive index structure functions, laser propagation experiments, remote sensing and monitoring of turbulence parameters, numerical simulation of optical propagation, control of adaptive optics systems, and other pertinent topics.

The workshop fulfilled its purpose, among others, of initiating possible joint research including collaborative flight experiments with the agencies and institutions represented at the workshop, taking advantage of some of the unique capabilities that the Dryden Flight Research Facility and UCLA can offer.

NASA's Goldin Honored by UCLA SEAS

During last October’s School of Engineering and Applied Science 29th Annual Recognition Dinner, the 1993 Alumnus of the Year Award was given to Richard S. Simonsen of the Aerojet Corporation and the Industry Citation Award was given to NASA Administrator Daniel Goldin. The Industry Citation Award is presented each year to a non-alumnus for distinguished achievements and outstanding contributions to the engineering field and for support of higher education. Goldin was unable to attend the dinner due to series of meetings in Moscow directed at establishing cooperation with the former Soviet Union on a number of aeronautics and space projects.

In a videotaped acceptance speech, Goldin lauded the education offered at UCLA’s School of Engineering, and challenged students to “zealously nurture your creativity, your innovation, but beware of applications.”

“Seek opportunities to understand how theories apply to producing a product. I’m convinced that science and technology is the way to retain our status as a value-added society,” Goldin said.

In addition to a number of student and faculty honors, former NASA Ames Research Center scientist, Dr. J. John Kim, who joined the faculty of the MANE department last fall, was congratulated on becoming the new Rockwell International Professor of Engineering endowed chair.

(Thanks to Bill Andrews of UCLA SEAS PAO for his assistance with the above article.)

The Research Roundup highlights and summaries were submitted by graduate students and/or their professors. Their efforts are greatly appreciated. Respective NASA technical monitors and project titles are listed alongside.

UCLA Experiment Flies on F-104

The UCLA transverse jet experiment flew 5 evening flights on the F-104/#826 between January 26-31, 1994. During those flights, planar laser-induced fluorescence (a traditionally ground-based wind-tunnel flow visualization technique) was achieved for the first time ever in flight, using a Nd-YAG laser to fluoresce an iodine-seeded nitrogen jet. Jet trajectories and mixing patterns were obtained for crossflow Mach numbers 0.8, 0.9, 0.95, 1.05, 1.2, 1.4, 1.5, 1.6, 1.8, a range which wind-tunnels have not previously explored. Three different upstream flow configurations were examined: 1. uniform crossflow, 2. flow over a rearward-facing step, one step height upstream, 3. flow over a rearward-facing step, four step heights upstream. Each flight acquired up to 8 different test conditions (Mach vs. altitude). Each test point produced 7 seconds of real-time video images, at 30 frames per second. Each frame has been computer digitized and is currently being studied and compared with numerical models. Prof. Owen Smith of ChemE and Prof. Ann Karagozian of MANE are co-PIs. Former GSR is Charles Wang (MANE). NASA monitors are Al Bowers and Ken Iliff. NASA research pilots were Rogers Smith, Jim Smolka, and Tom McMurtry.

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FSRC Research Roundup

Anindita Datta / Prof. Wurtele (Atmos. Sci.): L. Jack Ehernberger (XRA)
Numerical Modeling of Atmospheric Transients for High-performance Aircraft
Professor Morton Wurtele, post-docs Robert Sharman, Dan Landau and graduate student Anindita Datta are working on identifying and quantifying environmental conditions that pose as potential hazards to high performance aircraft. They have studied the flow conditions under which a disturbance originating in the troposphere can propagate into the middle atmosphere, also the conditions under which a propagating disturbance will break down and generate large amplitude smaller scale components, including turbulence. When such a breakdown occurs, attempt is being made to characterize the resulting spectrum and to understand its potential impact on high-performance aircraft and future hypersonic configurations.

Chris Garrett / Profs. Apostolakis and Catton (MANE): Vicki Regenie(XRD)
Probabilistic Risk Assessment and Management in Support of NASA
We are currently in the process of developing a set of prototype software tools for implementing the Dynamic Flowgraph Methodology (DFM). DFM is a methodological approach for modeling and analyzing the behavior of embedded software systems for the purpose of reliability/safety assessment and verification. The tools we are developing include a graphical model editor to assist a user in building DFM system models, and a model analyzer/fault tree-builder which, based on the control flow of the software and the causal relationships between system variables expressed in the model, develops timed fault trees which identify the hardware and software states which can lead to certain events of interest. This information can be used to identify how failures can occur in a system and to identify an appropriate testing strategy based on an analysis of system functional behavior.We plan to demonstrate the use of these tools by applying them to a case study involving the RFCS flight control system of the F-18 HARV aircraft. The particular problem under investigation for the RFCS software will be that of determining that RFCS cannot send any erroneous hardover commands to any control surfaces.

Gustave Stroes / Profs. Catton and Dhir (MANE): Bob Curry (XRA)
Leading Edge Cooling
Research continues on the application of heat-pipe technology to the cooling of the leading edges of hypersonic vehicles. Current work is focused on determining an optimized groove shape for the liquid side evaporator/condenser section. Experiments are being run using two channelled flat plate test sections which are heated from below. One plate has triangular grooves while the other has sinusoidal grooves, both shaped to provide the same cross-sectional area for liquid make-up flow. It appears that the sinusoidal channels can withstand higher heat inputs before disruption of the make-up flow occurs. This was suspected in advance since the sinusoidal grooves allow for large amounts of ultra-thin film evaporation from the smooth ridges between channels. Future studies will further examine the effect of vibration on the ability of various wicking structures in providing adequate make-up flow rates.

Guohua Wang / Prof. Balakrishnan (EE): Ken Iliff (XR)
Modeling, Identification, and Control with Application to Flight Vehicles
This summary presents the results of our study of stochastic adaptive control theory and its applications to flight control systems. The general Linear Quadratic Stochastic Adaptive Control (LQSAC) problem can be stated as follows. Given a stochastic system represented by linear state and observation equations, find an adaptive control law which minimizes a quadratic cost functional.

FSRC Research Roundup - *continued*

We have designed an (asymptotically) optimal stochastic adaptive controller for the important class of LQSAC problems where the system control derivatives are uncertain. Our SAC (stochastic adaptive control) design incorporates a state and parameter estimator, and a LQG controller, and is automatic (in that it uses the state noise process as the identifying excitation). We have established almost sure convergence of parameter estimates, asymptotic optimality of the adaptive control performance, as well as L_p stability of the adaptively controlled system.

Several important aspects of practical applications are examined through computer simulations of an aircraft being flown in atmospheric turbulence where the gust response in the angle of attack is to be minimized, and including the speed of adaptation, optimal choice of 'lambda', approximation of the threshold value of gust intensity, etc.. The results indicate that the parameter estimation algorithm converges so that asymptotically optimal performance is achieved, i.e. the gust response in the angle of attack is reduced as it would be had the control derivatives been known. Simulations also demonstrate that the SAC design performs well in heavy turbulence. In fact, the rate of adaptation increases with the gust noise level. It is further demonstrated that the SAC performs well when the control derivatives vary slowly. Full parameter adaptation will be the topic of continuing research.

Jeffrey Kong and Flavio Lorenzelli / Prof. Yao (EE): Steve Thornton (XRS)
New Non-Linear Least-Squares (LS) and Total LS Techs. for Load Meas. Probs.
Jeffrey Kong received his Ph.D. in January 1994. His thesis, "The Accuracy of Parameter Estimation in System Identification of Noisy Aircraft Load Measurement", was motivated by the NASA-DFRF load measurement problem. The objective of the problem is to accurately predict the load experienced by an aircraft wing during flight, determined from a set of calibrated load and gage response relationships. We can model the problem as a black box input-output system identification from which the system parameters are to be estimated. Traditional LS techniques and the issues of noisy data and model accuracy are addressed. SVD techniques for data reduction are studied and the equivalence of the Correspondence Analysis (CA) and Total Least Squares Criteria are proved. We also looked at nonlinear LS problems with wing load data from NASA's AFTI/F-111 aircraft. Neural Network (NN) techniques were applied to this problem because NNs do not require prior information on the exact model of the system. Simulation results for the NN methods used in both the single load and the "warning signal" problems are both useful and encouraging. The NN design methodology is also presented. Jeff, Flavio, and Prof. Yao are currently preparing several papers for publication. *(This project and grant have concluded.)*

Qian Lin / Prof. K.L. Wang (EE): Rod Bogue (XRF)
Investigation on Refraction Index Patterns of Wind Flow
The fabricated Mach-Zender interferometer has been aligned and clear interference fringes have been obtained. At present, we have established the lasers sources, which cover the visible and near infrared wavelengths range. The detection system has been set up which includes a visible-infrared vidicon, a synchronized TV monitor and a Si and a Ge detectors. A "wind tunnel" chamber has been fabricated and is currently under testing. We anticipate that we will begin the optical experiments in a couple of weeks. In the initial optical experiments, we will start the collection of interferogram data for flow patterns, followed by the signal processing in order to

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Other factors that can influence sonic booms include: weight and shape of the aircraft, altitude, angle of attack and flight path, weather, atmospheric conditions, aircraft maneuver, and ground terrain features.

Measured in pounds per square foot, overpressure and underpressure denote the increase and decrease over the normal atmospheric pressure at sea level (14.7 psi; 101.325 kPa). At one pound overpressure, no damage to structures would be expected. Overpressures of 1 to 2 pounds are produced by supersonic aircraft flying at normal operating altitudes. Some public reaction could be expected between 1.5 and 2 pounds. As overpressure increases, the likelihood of structural damage and stronger public reaction also increases. Tests, however, have shown that structures in good condition have been undamaged by overpressures of up to 11 pounds.

During the landing of the orbiter Discovery on mission STS-26, Oct. 3, 1988, overpressures recorded on the ground revealed that the intensity was 1.06 pounds in the Santa Barbara area as Discovery crossed the coastline at a speed of Mach 4.37 at an altitude of 115,400 feet. Intensity rose to 1.15 pounds over the Santa Clarita Valley, then increased to 1.75 pounds over Palmdale and Lancaster, as Discovery headed into Edwards AFB, where it "boomed" the base with 1.25 pounds overpressure.

By comparison, the British Airways Concorde SST exhibits 1.94 pounds of overpressure at Mach 2 and 52,000 feet. The SR-71 produces 0.9 pounds at Mach 3 and 80,000 feet. An F-104 at Mach 1.93 and 48,000 feet generates a 0.8 pound shock wave on the ground.

Due to NASA's current interest in the High-Speed Civil Transport (HSCT), active research is underway to study methods of reducing sonic boom intensity.

assess the change of index of refraction. From the pattern of the refractive index, the density difference will be obtained.

Ira Nydick / Profs. Friedmann and Zhong (MANE): Kajal Gupta (XR)
Aerothermoelasticity & Aeroservoelas. of a Gen. Hyp. Veh.
The general equations describing the nonlinear fluttering oscillations of shallow, curved, heated orthotropic panels have been derived. The formulation takes into account the location of the panel on a generic hypersonic vehicle. Computer solutions are obtained using Galerkin's method combined with direct numerical integration in time to compute stable limit cycle amplitudes. Results have been obtained for isotropic and orthotropic simply supported panels, both curved and flat, for various temperature distributions. Present effort is focused on improving the panel curvature model by using the Macsyma symbolic manipulation software program to perform the algebra-intensive derivation. Future research goals include modeling the hypersonic aerodynamic loads using computational fluid dynamics (CFD) and incorporating a structural model representative of a wing on a typical hypersonic vehicle.

Dongrin Kim and Jose Diaz / Prof. Yao (EE): Phil Hamory (XRF)
Spread Spectrum Telemetry Comm. on Aircraft Power Lines
Professor Yao and a group of students are planning to program a high level spread spectrum system simulation using a software package called 'Simulink' which is a subset of 'Matlab'. This simulation would model a multiple sensor communication system on board experimental aircraft. This programming tool allows user defined block diagrams to be incorporated with the system functions and blocks defined in the package. We have been working in the area of code generation for the spread spectrum users and the probability of error calculation using various analytical methods. Normally, Gold code is adopted for the system with the multiple access system. Software generation of the Gold code has been completed and will be included in the system simulation. We are also considering the synchronization and tracking part of the receiver a crucial portion of the system. More study on this will be done in the future. Right now we are trying to learn more about the new simulation program 'Simulink' since no one has extensive experience on this yet. Once we are used to the new system, hopefully things can be done with more efficiency.

Tim Gerk and Annik Neill / Prof. Karagozian (MANE): Stephen Corda (XRP) and Ken Iliff (XR)
Modeling of Combustion Processes
The lobed injector/burner project involves the modeling and development of a novel fuel injector which is capable of reducing NOx emissions from high speed aircraft engines such as the High Speed Civil Transport (HSCT) or the Advanced Subsonic Engine.

The 2-D, unsteady analytic model of diffusive mixing has been developed for a flowfield composed of an infinite series of vortex pairs. The fuel is initially located in a sinusoidal strip with an inflection point coinciding with each vortex. This is an approximation of the flowfield found at the trailing edge of the lobed injector. The model is an expanded version of the single fuel-oxidizer interface which is strained by a viscous vortex. Ignition and reaction chemistry may be examined by augmentation of this model.

Tim is using the model currently to predict the mixing behavior of fuel injected rearward between two lobed plates. These plates have a streamwise flare and transverse oscillation which will shed streamwise vorticity into the downstream flow, approximately as a series of vortex pairs. We observe computationally that circulation due to a potential vortex significantly augments and accelerates the process of diffusive mixing of fuel with oxidizer. Tim predicts spatial concentration distributions which may be confirmed by anticipated PLIF measurements in the mixing/combustion tunnel under construction. Future in-flight experiments with the lobed injector are also being studied, with a design similar to that used in the transverse jet laser imaging experiments.

In the numerical modeling, Annik is developing a code based on the ENO scheme of Shu and Osher to simulate the lobed injector flowfield. The ultimate aim is to simulate fully the 3D flowfield as an effectively 2D, transient flowfield, with mixing but probably without full chemistry for the reaction (probably a one-step mechanism will be examined).

Brian Dempsey and Ben Tan / Prof. Mills (MANE): Bob Quinn (XRS)
Fluid Flow & Ht. Conv. Studies for Actively Cooled Airframes
The jet impingement experiment is progressing towards the next phase, data gathering. Currently all the major equipment and instruments have been received and are in the process of being tested or installed into the experimental rig. The last task to be completed before testing can begin, is to write the data acquisition and data reduction software. The data acquisition software should be rather straightforward, however it will require integrating hardware and software from two different manufacturers to form a unique application that neither company has ever tried. The data reduction software is the solution to a complicated conduction problem. The complication occurs because instead of the usual conduction problem where given certain boundary conditions, temperature can be calculated, this experiment poses the inverse problem of calculating the boundary conditions given certain temperatures. The result will be an elaborate computation involving multiple integrations, interpolations, and iterations. It is expected that the data gathering phase will begin sometime this spring.